

# Broadband Design of Slotted $TE_{21}$ Second Harmonic Gyrotron Backward-Wave Oscillator

N. C. Chen, T. H. Chang, and C. F. Yu

Department of Physics, National Tsing Hua University, Hsinchu, Taiwan

**Abstract-** Second harmonic gyrotron backward-wave oscillator (gyro-BWO) is a promising tunable source with only half the magnetic field requirement. But these merits have long been impeded by the transverse and axial modes competition as a result of lower efficiency. This study employs a slotted structure as a mode selector for suppressing the persistent low order transverse mode. In addition, an optimized two-step tapered structure is adopted to stabilize the high order transverse modes and axial modes. The interaction efficiency and the tuning bandwidth were greatly enhanced in the meanwhile. As a calculated result, a stable, ka-band, slotted second harmonic gyro-BWO is capable of producing an efficiency of 23% and a 3-dB tuning bandwidth of 9% at 5 A and 100 kV.

## I. INTRODUCTION

The gyrotron backward wave oscillator (gyro-BWO) based on electron cyclotron maser interaction (ECM) is a promising candidate for continuously tunable source. Harmonic gyrotron, which greatly lowers the required magnetic field, has been a growing interest. However, its' subject to modes competition and high oscillation threshold have long limited the capability. Slotted boundary was conducted to gyrotron in 1980s and was found able to decrease the requisite beam power for harmonic operation [1]. Slotted third-harmonic gyro-TWT amplifier was developed and demonstrated in UC Davis [2-4]. However, little research has been done on the slotted harmonic gyro-BWO. This study employed the slotted structure with axial geometry optimization for  $TE_{21}$  second harmonic gyro-BWO which provided broad tuning bandwidth as well as the stability for transverse mode and axial modes competition.

## II. SLOTTED STRUCTURE FOR TRANSVERSE MODE COMPETITION

The cutoff frequency  $k$  of  $\pi$  mode drops more rapidly than other slotted waveguide modes with the increase of slot radius ratio  $b$  over  $a$ . To fix the  $k$  at  $\pi$  mode operation, the respective dispersion curve of competing modes shift up from smooth-bore to slotted-bore waveguide, as shown in Fig. 1. The intersection position which denotes the resonance condition varied so dramatically that the  $\pi$  mode operation has the freedom to select the favorite condition for solution of transverse modes competition. The most competitive  $TE_{11}^{(1)}$  mode is out of resonance in magnetic tuning range with a ratio of 1.15. As the ratio up to 1.5, the threshold beam power is half, but side azimuthal component interaction  $TE_{-11}^{(2)}$  and  $TE_{01}^{(3)}$  mode might be induced.

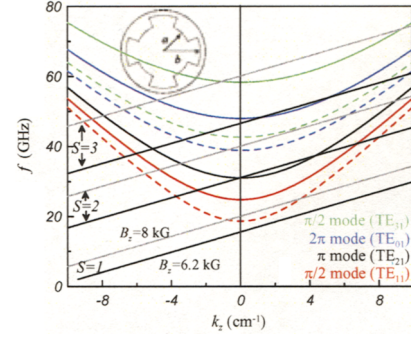


FIG. 1 Frequency- $k_z$  diagram of a second harmonic, Ka-band gyro-BWO for smooth-bore waveguide (broken line) and for 4-vane slotted waveguide with  $b/a=1.5$  (solid line).

## III. AXIAL GEOMETRY OPTIMIZATION FOR INTERACTION EFFICIENCY AND MODES COMPETITION

The down-taper structure would lead to a diversity of effective interaction length from  $k_z$ . The slow taper followed by a step taper in axial geometry was found to suppress unwanted modes competition. A Slotted waveguide ( $b/a=1.5$ ) in axial geometry of couple-out section ( $L_1$ ) combined with two-step interaction section ( $L_2+L_3$ ) is simulated in Fig. 2

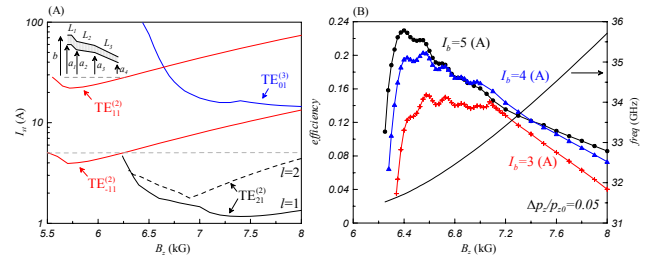


FIG. 2 (a) Start-oscillation currents versus magnetic field for several competing modes (b) Calculated efficiency and frequency versus magnetic field for several beam currents:  $I_b=3$ ,  $I_b=4$ , and  $I_b=5$ . Velocity spread assumed 5%.

## REFERENCE

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